Neural Networks for Identifying Civil Pilot's Operation Sequences

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Abstract. "Human Error", as we all know, is inevitable during the flight process of civil aircraft. It is one of the most significant reasons for civil aircraft accidents and incidents. Therefore, to identify and avoid "Human Error" is becoming more and more urgent.

In order to restrict the influence of "Human Error", the wrong sequence of civil pilot's operation must be detected and a warning should be provided for pilot or intelligent action to correct the wrong sequence of operations.

A set of effective behavior coding system is developed for expressing the pilot's operations. Pilot's operation behaviors can be quantized and operation sequences can be coded. And the set of effective pilot's behavior coding system plays an important role in reducing the probability of flight accidents caused by "Human Error".

For identifying whether the pilot's operation sequence is right, a database of codes of pilot's operation sequences should be built. By comparing with the codes in the database, a wrong operation sequence can be detected. Generally speaking, the database containing codes of all possible correct and wrong operation sequences is difficult to set up. As a matter of fact, the database we can develop is just a part of all possible codes of operation sequences. Therefore, those naturally correct operation sequences but not in the database may be detected as wrong ones by comparing with the correct codes in the database. This paper adopts neural networks to identify any codes of operation sequences (in database and not in database) accurately. The incomplete database is trained by neural networks to find the rule for identifying whether a specific operation sequence is correct. If the specific pilot's operation sequence disobeys the rule, a warning will be provided for pilot to rectify the operation, which reduces the probability of accidents caused by "Human Error" and realizes the intelligent identifying function.

Keywords: Human Error, Operation Behavior, Coding system, Neural Networks.

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1 Introduction

Civil plane pilot assumes tasks of piloting and airplane management in the flight profile from taking off to landing. It may lead to serious incidents or even huge aeronautical disasters once there exist human errors in the operational processes of airplane equipment that requires high safety or well functions.

In recent years, with the development of automation of civil airplane, civil aviation incidents that caused by mechanical equipment and automation system decreased, meanwhile, proportion of human errors increased by years. Statistical analysis shows that the proportion of incidents caused by human errors is very high. Generally speaking, the proportion of incidents caused by human errors is more than 70%.

Therefore, to enhance the safe level of civil airplane heavily, inappropriate operational actions of civil airplane pilots should be in control and incline.

It is known to all that everyone makes mistakes. The thought that flight safety can be guaranteed by expecting no human errors is unreal. We can only hope that mistake avoidance of the plane itself and function of fault-tolerance can lower the rate of incidents that caused by human errors.

In this paper, BP neural network is adopted to find the rule for identifying whether a specific operation sequence is correct. If civil pilots perform the wrong operation sequence, the operation will be detected as human error by BP (Back-Propagation) neural network. Then such operations will not be carried out, which prevent the accidents caused by human error.

The prerequisite of the training of BP neural network is the quantitative description of civil aviation pilot's fundamental operational actions, i. e., to build code rules of civil aviation pilot's basic operational actions. For this reason, this project introduce the coding system for civil aviation pilot's basic operational actions, realizing standard expression and quantitative description, providing a new settle thought for computer auto detection and identification of human errors, enriching present functions of warning and alarming, lowering the difficulty of finding mistakes, providing references for error prevention and risk aversion, improving flight safety level in essence.

2 Basic Operational Actions and Definition of Characteristic Actions

Although operations of pilots in flight process vary, they were built by several basic movements. Our code object is civil planes' basic operation action of pilot. We fixed 19 basic movements, which is called 19 therbligs, see table 1.

Table 1. Therbligs

Category	Name	Symbol	Definition
1	Reach	Re	Movement that approaches object
2	Grasp	G	Movement that holds object
3	Whirl	W	Movement that makes object pivot
4	Press	Ps	Movement that makes object move in the direction of force
5	Pull Out	PO	Movement that makes object move in the direction of source force
6	Tread	T	Movement that controls movement of object by foot
7	Release	Rl	Movement that departs object
8	Inspect	I	Movement that compares to standard
9	Report	Rp	Movement that expresses current situation of object
10	Search	Sh	Movement that fix the position of object
11	Select	St	Movement that select object
12	Plan	Pn	Movement that delays for planning operational program
13	Hold	H	Movement that keeps the statement of object
14	Position	P	Movement that adjusts the position of object
15	Pro-Position	PP	Movement that places object to avoid 'position' movement when object is used
16	Rest	Rt	Movement for rest
17	Unavoidable Delay	UD	Inevitably halt
18	Avoidable Delay	AD	Evitable halt
19	Find	F	Movement that finds object

3 Design of Code of Basic Operational Actions

3.1 Dimensions of Code

Code is the only mark of code object, except for the functions that it can precisely define main part, movement, operation object and time, provide information on code object, distinctly reflect categories, attributes, features, etc. of code object, code of measures that are used to reduce human errors and redundancy code that is used to avoid miss of code in transmission are included. Six kinds of code structures are adopted now: hierarchy code, abbreviation code, sequence code, condition code, check code and compound code. We apply following code structure according to requirement of code content and every code structure's feature under code principles.
Fig 1 Code Structure of Pilot's Basic Operational Actions.

Abbreviate code + Sequence code + Condition code + Position Code + Time code + Check code

Fig. 1. Code Structure of Pilot's Basic Operational Actions

Abbreviate Code. Operational main part that involved in the process of pilot's actual operation-human's body regions are few, and there are only 19 pilot's basic operational therbligs, then we can use the way of mnemonic code, easily to grasp. Mnemonic code belongs to abbreviate code and is commonly used. It selects several critical letters from name and specification of code object to be code or part of code, with way of association to help memorize, easy to understand.

Fig 2 are the expressions of operational main part and abbreviate code of basic action, two letters for body regions, 1~2 letters for basic action. See operational main part and abbreviate code of basic action in table 2.

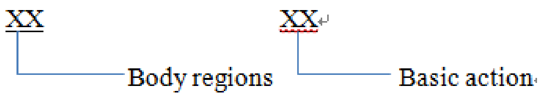

Fig. 2. Structure of Abbreviate Code

Table 2. Body Regions and Abbreviate Code of Basic Action

Body Regions						
Hand (H)		Foot (F)		Head (H)		Else(Es)
Left hand (LH)	Right hand (RH)	Left foot (LF)	Right foot (RF)	Eye (HE)	Mouth (HM)	Else(Es)
Basic Actions						
Reach (Re)	Grasp (G)	Whirl (W)	Press (Ps)	Pull Out (PO)	Tread (T)	Release (Rl)
Inspect (I)	Report (Rp)	Search (Sh)	Select (St)	Plan (Pn)	Hold (H)	Position (P)
Pre-position (PP)	Rest (Rt)	Unavoidable-delay (UD)	Avoidable-delay (AD)	Find (F)		

Sequence Code. In a certain phase of flight, it may involve operating a same object several times or repeating a basic action in the process of operating an object, thus, we should position the action by sequence code to describe the difference in the process. Sequence code is simple and commonly used. It put positive integers or alphabets to code objects. Simple to code, well to use, convenient to manage, easy to add, have no limits for the order of code object. However, it is hard to memory for the code itself does not provide any information about code object.

Fig 3 is the expression of sequence code.

Fig. 3. Structure of Sequence Code

Among above, order number A-the M times operation for a same operational object in a certain flight phase, the span is 1~99;

Order number B-repeat a basic action N times in M times operation of operational object, the span is 1~99.

Condition Code. In order to keep the continuity of action, in case of action omission in the process of pilot's operation and reduction or avoidance of human errors, we classify the attributes of basic actions into 3 groups, which are denoted by condition code. To select the right code to satisfy the demand and combine them in a predefine order in use.

Condition code (condition combination code) is commonly used in the system of surface classification, entry in each surface is coded by its principle. Combining code in each surface as needed and order predefined in use. Code structure is flexible; it can be single or combination. It is convenient to change and expand for it is classified by surface. A condition code can reflect the whole recorded information features, as well as part features when it is partly used. It is elastic and specially suitable for dynamic compound quick inquiry, summing and other operations. Condition code has much more values in the design of information management system. However, the volume use rate of condition code is low.

The expression mode of condition code is shown as figure 4. Overlapping attribute of pilot's basic operational actions, the way of classification and concrete meaning of connect attribute are shown as table 3. If pilot's operational actions do not comply with the request of condition code, alarm can be used to draw pilot's attention.

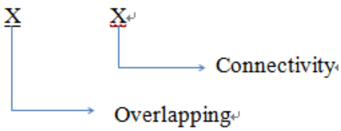

Fig. 4. Condition Code Structure

Table 3. Action attribute classification

	code	meaning
Overlapping	A	This action cannot overlap with other actions (except independent actions).
	B	This action can overlap with other actions.
	C	Totally independent, can overlap with any actions
Connectivity	1	Connect with AB category actions in required time
	2	Connect with any other overlapping actions in required time.

Position Code. As operational object is the object used in a specific flight phase, we should consider two aspects on operational object: flight phase and use object. Flight phases of Airbus are detailed and there is a lot of equipment in cockpit. The way of coding of all phases and equipment just start from 1 may increase the complexity of coding procedure. Therefore, we can apply layer code, breaking down from whole to part, to help code.

Layer code belongs to the kind that is commonly used for linear taxonomic hierarchies. It is a code that ordering by the relation of subordinate of object of classification and hierarchies. The code is cracked into several hierarchies, which is in accordance with the classification of code object. The code can definitely express categories of the classification objects, have strict subjection relations, and each hierarchy is meaningful. It is easy for computer to sum and summary as it has easy structure and high capacity. We should do some classifications before design, then to code and establish instruction of classification.

In addition, to indicate the shape features of equipment of cockpit from code and restrict action type, we can define the shape attribute by condition code; as a result, the position code of cockpit equipment consists of hierarchy code and condition code, which named compound code. Compound code includes two or more independent codes, flexible, easy to expand and mark part can be nimble used.

Therefore, we have a clear expression of the position of used operational object in the process of flight operation of pilot. The full expression is showed as Fig. 5. Hierarchy code and operational equipment's condition code are expressed as table 4;

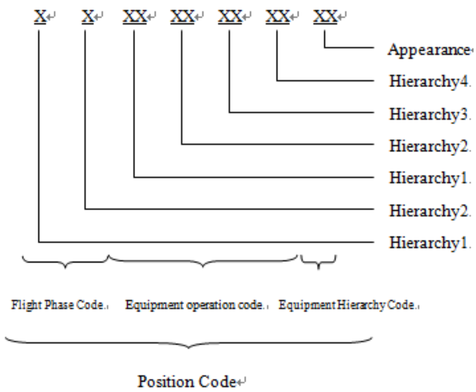

Fig. 5. Position Code Expression

If to adjust impulse force by using throttle lever in phase of climbing, throttle lever's position can be denoted as 4103100011. 8,9-bit code for 0 is the same with other classification median plus, no special significance. If transfer display mode in the phase of take-off taxi, then navigation mode button classification code is 3202031007.

Table 4. Flight Phase Layer Code

Flight phase							
Start up （1）	Taxi （2）	Take off （3）	Climb （4）	Cruise （5）	Descent （6）	Approach （7）	Landing （8）
Start up	Taxi	Take off	Climb	Cruise	Descent	Approach	Landing
Start up （1）							
Engine auto starts up （1）				Engine manual starts up （2）			
Taxi （2）							
Propulsion push out （1）	Taxi and steering （2）	Brake check （3）	light control inspection （4）	Take-off fragmentary verification （5）			
Take off （3）							
Propulsion set （1）	Taxi （2）	Rotation （3）	Minus propulsion altitude （4）	Acceleration altitude （5）			
Climb （4）							
Climb monitor （1）	Speed change （2）	Acceleration climb （3）	Set barometer reference （4）	Terminate landing light （5）			
Terminate seat belt indicator light （06）	EFIS options （07）	Check radio navigation page （08）	Transfer second flight plan （09）	Check best/highest altitude （10）			
Cruise （5）							
Use of Flight Management System （1）	Gradient climb	Fuel monitor （3）	Approach preparation （4）				
Descent （6）							
Guide and monitor （1）				Mode transfer （2）			
Approach （7）							
ILS approach （1）	Imprecise approach （2）	Rotation approach （3）	Visual approach （4）	Precise approach （5）			
Landing （8）							
Trim （1）	Call （2）	Dive （3）	Taxi （4）	Brake （5）			

Table 5. Appearance Attribute Condition Code

Appearance Attribute				
Button (01)	Swtich(no cover) (02)	Cover switch (03)	Electirc switch (no cover) (04)	Electric switch（with cover）(05)
Electric switch(Spring attachment) (06)	Screw (07)	Select button (08)	selector (09)	keystoke (10)
Stick (11)	Wheel (12)	Handle (13)	Treadle (14)	Light (15)
Indicator light (16)	Monitor (17)	Indicator (18)	Hub (19)	Storage (20)
Pack (21)	Mask (22)			

Time Code. Generally speaking, the proportion of incidents that caused by human error in civil aviation incidents is more than 70%. Once a motion absent happened in the operational process, the consequence will be very serious, even huge aviation disastrous incidents. In case of omission of pilots' operational actions, the condition code requires pilot should complete a certain action at a regulatory time which may avoid action omission. The times involved in this process are the last time of action itself and time between this action and next action. We can use time code to denote time, that is, to add time property to code. The format of time code is: xxHxxMxxS, of which xx stands for number. Time code can be expressed as figure 6.

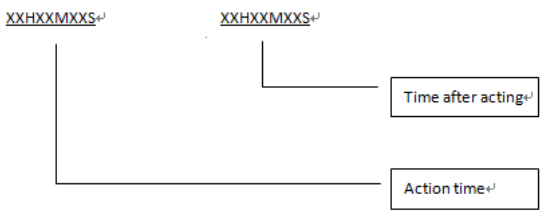

Fig. 6. Time Code Structure

Check Code. Generally, Check bit in the coding structure is the token of check code. In the process of structure designation of primary code, computing check bit attached to primary code with prescriptive mathematical method in advance, then the computer would calculate check bit in the same way when use the check code, it is definitely clear to see whether the input is right by comparing these two check bits. Cyclic redundancy code (CRC) is one of the most common used check bits. Cyclic redundancy code produced at sending terminal is sent to receive terminal by adding to the back of information bit. To check the received information with the same algorithm that produces cyclic redundancy code, if there is a mistake, then receive terminal makes a resend notice. CRC is good at error detection, low cost, and easily coded, while it is hard to detect errors made by 2 bits or more.

4 Standard Operation Sequence

In this paper, the operations of Airbus 320 in the stage of climb are taken as an example for explaining the coding system. In order to be familiar with the pilots' operations and guarantee the safety of flight, the codes of operation in the stage of climb are shown as table 6.

Table 6. Operations of Airbus 320 in the Stage of Climb

Operation Step	Operation code
1.Monitor Climb	RHRh0101B1N04010301100100H00M01S00H00M01S29111
	RHPs0101B1N04010301100100H00M01S00H00M01S29111
	HEIt0101B1N04010301100100H00M01S00H00M03S29111
	RHRl0101B1N04010301100100H00M02S00H00M02S29111
	LHRh0101B1N04010302130100H00M02S00H00M02S29111
	LHPs0101B1N04010302130100H00M03S00H00M01S29111
	HEIt0101B1N04010302130100H00M01S00H00M01S29111
	LHLl0101B1N04010302130100H00M01S00H00M01S29111
2.Change Velocity	HMRp0101C1N04020000000000H00M02S00H00M01S29111
	EHRh0101B1N04020201021000H00M01S00H00M01S29111
	EHGp0101B1N04020201021000H00M01S00H00M01S29111
	EHWl0101B1Y04020201021000H01M00S00H00M01S29111
	EHPO0101B1N04020201021000H00M01S00H00M01S27012
	EHRl0101B2N04020201021000H00M01S00H00M01S29111
3.Accelerate Climb	HMRp0101C1N04030000000000H00M03S00H00M01S29111
	EHRh0201B1N04030201120100H00M01S00H00M01S29111
	EHPs0201B1Y04030201120100H00M01S00H00M01S29111
	EHRl0201B1N04030201120100H00M01S00H00M01S29111
	EHRh0201B1N04030201051000H00M01S00H00M01S29111
	EHPs0101B1Y04030201051000H00M01S00H00M01S29111
	EHRl0101B1N04030201051000H00M01S00H00M01S29111
	HEIt0101B2N04030101001700H00M02S00H00M01S29111
4.Adjust GasPressure Meter	RHRh0101B1N04040202020700H00M01S00H00M01S29111
	RHGp0101B1N04040202020700H00M01S00H00M01S29111
	RHWl0101B1Y04040202020700H01M00S00H00M01S29111
	RHRl0101B1N04040202020700H00M01S00H00M01S29111
	HEIt0101B2N04040101001700H00M02S00H00M01S29111

Table 6. (*continued*)

5.Adjust Cruise Altitude	HMRp0101C1N04050000000000H00M03S00H00M01S29111
	RHRh0101B1N04050301090100H00M01S00H00M01S29111
	RHPs0101B1Y04050301090100H00M01S00H00M01S29111
	RHRl0101B1N04050301090100H00M01S00H00M01S29111
	RHRh0101B1N04050301010100H00M01S00H00M01S29111
	RHPs0101B1Y04050301010100H00M01S00H00M01S29111
	RHRl0101B1N04050301010100H00M01S00H00M01S29111
	RHPs0101B1N04050301210100H00M01S00H00M01S29111
	RHRl0101B1Y04050301210100H00M03S00H00M01S29111
	RHPs0102B1Y04050301210100H00M03S00H00M01S29111
	RHPs0103B1Y04050301210100H00M03S00H00M01S29111
	RHRl0101B2N04050301210100H00M01S00H00M01S29111
6.Engine's Anti-icing	EHRh0101C1N04060419020400H00M01S00H00M01S29111
	EHPs0101B1Y04060419020400H00M01S00H00M01S29111
	EHPs0101B1Y04060419030400H00M01S00H00M01S29111
	EHRl0101B2N04060419030400H00M01S00H00M01S29111
7.Tilting Radar	EHRh0101B1N04070307040700H00M01S00H00M01S29111
	EHGp0101B1N04070307040700H00M01S00H00M01S29111
	EHWl0101B1N04070307040700H01M00S00H00M01S29111
	EHRl0101B1N04070307040700H00M01S00H00M01S29111
8.Turnoff Landing Light	EHRh0101B1N04080422060200H00M01S00H00M01S29111
	EHPs0101B1N04080422060200H00M01S00H00M01S29111
	EHPs0101B1N04080422070200H00M01S00H00M01S29111
	EHRl0101B1N04080422070200H00M01S00H00M01S29111
9.Turnoff Seatbelt Light	EHRh0101B1N04090425010200H00M01S00H00M01S29111
	EHPs0101B1N04090425010200H00M01S00H00M01S29111
	EHRl0101B1N04090425010200H00M01S00H00M01S29111
10.EFIS Option	RHRh0101B1N04100202090100H00M01S00H00M01S29111
	RHPs0101B1N04100202090100H00M01S00H00M01S29111
	RHRl0101B1N04100202090100H00M01S00H00M01S29111
	HEIt0101B1N04100301071700H00M02S00H00M01S29111
11.Check Radio Navigation	RHRh0101B1N04110301140100H00M01S00H00M01S29111
	RHPs0101B1Y04110301140100H00M01S00H00M01S29111
	RHRl0101B1N04110301140100H00M01S00H00M01S29111
	HEIt0101B1N04110301071700H00M02S00H00M01S29111
12.Call Second Flignt Plan	RHRh0101C1N04120301160100H00M01S00H00M01S29111
	RHPs0101B1Y04120301160100H00M03S00H00M01S29111
	RHRl0101B2N04120301160100H00M01S00H00M01S29111
13.Check Ideal/High Altitude	RHRh0101B1N04130301090100H00M01S00H00M01S29111
	RHPs0101B1Y04130301090100H00M03S00H00M01S29111
	RHRl0101B1N04130301090100H00M01S00H00M01S29111
	HEIt0101B1N04130301071700H00M02S00H00M01S29111

5 BP Neural Network for Identifying Operation Sequence

Rumelhart, McClelland and their colleagues realize the importance of neural networks in dealing with the information. They developed the learning algorithm of BP network in 1985, which makes the assumption of multi-layer network come true.

BP network can deal with any nonlinear mapping problems. It is mainly used in four aspects: approximation of function, mode recognition, classification, and data compression.

Basically, two pilot's actions can be linked as one operation sequence. For example, (RHRh0101B1N04010301100100H00M01S00H00M01S29111, RHPs0101B1N040-10301100100H00M01S00H00M01S29111) is an operation sequence. Therefore, the number of input channel of BP network is chosen as two. The second code is executed after the first code. And the code need to be transferred into binary system, for example, RHRh0101B1N040103011001-00H00M01S00H00M01S29111 is transferred as 01010010 01001000 01010010 01101000 0000 0001 0000 0001 01000010 0001 01001110 0000 0100 0000 0001 0000 0011 0000 0001 0001 0000 0000 0001 0000 0000 01001000 0000 0000 01001101 0000 0001 01010011 0000 0000 01001000 0000 0000 01001101 0000 0001 01010011 0010 0111 0001 0001 0001(This process is simple, and will not be introduced in this paper). The BP neural network is illustrated as Fig. 7. The network has two neurons and single hidden layer. The output result of right operation sequence is defined as 1, while the output result of wrong operation sequence is defined as 0. For example, the output of input (RHRh0101B1N04010301100100H00M01S00H00M01S29111, RHPs0101B1N040-10301100100H00M01S00H00M01S29111) is 1, however, 0 for (RHPs0101B1N040-10301100100H00M01S00H00M01S29111, RHRh0101B1N04010301100100H00M-01S00H00M01S29111).

The operation sequences of Airbus 320 in the stage of climb are chosen as database to train the BP neural network.

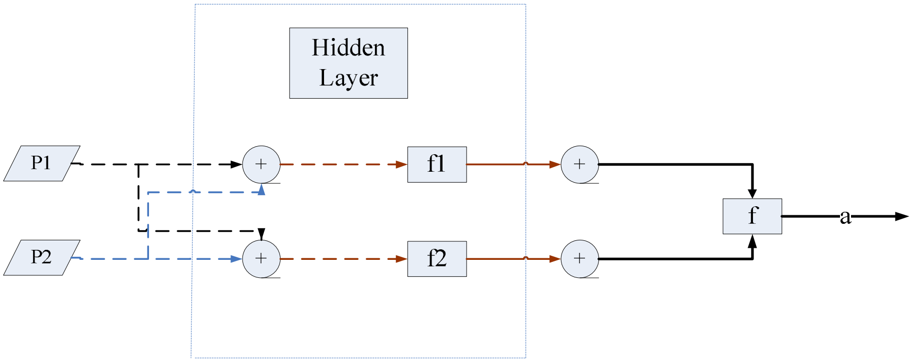

Fig. 7. BP Neural Network

After training, the BP neural network will deal with the operation sequences as table 7 (5 random demonstration examples).

Table 7. BP Neural Network Training Rseult

Input	Output	Result
(RHPs0101B1N04010301100100H00M01S00H00M01S29111, HEIt0101B1N04010301100100H00M01S00H00M03S29111)	1	√
(LHPs0101B1N04010302130100H00M03S00H00M01S29111, LHRh0101B1N04010302130100H00M02S00H00M02S29111)	0	√
(EHRh0201B1N04030201120100H00M01S00H00M01S29111, EHPs0201B1Y04030201120100H00M01S00H00M01S29111)	1	√
(EHRh0101C1N04060419020400H00M01S00H00M01S29111, EHPs0101B1Y04060419020400H00M01S00H00M01S29111)	1	√
(RHRh0101C1N04120301160100H00M01S00H00M01S29111, RHRl0101B1N04110301140100H00M01S00H00M01S29111)	1	×

6 Conclusion

In this paper, Basic operation code method is introduced, which providing a new thought for computer automatic detection and distinguishment of human error, enriching existing warn and remind functions and offering references for error prevention and risk avoidance. From the examples in table 7 in part 5, the accuracy of BP neural network is 4/5(80%), which means BP network does work but not ideal enough. Still some wrong operation sequences are not detected. Further work is focused on increasing the accuracy of network.